PAVONIS MONS FAN-SHAPED DEPOSITS - A COLD-BASED GLACIAL MODEL. D. E. Shean[1] and J. W. Head[1], [1]Brown University, David_Shean@Brown.edu, James_Head@Brown.edu

Introduction: Each of the three Tharsis Montes volcanoes on Mars has unusual fan-shaped deposits located exclusively to the northwest of each shield. The fan-shaped deposits of the Tharsis Montes generally share three major facies: 1) Ridged facies, 2) Knobby facies, and 3) Smooth facies. Here we examine the Pavonis fan-shaped deposits using new Mars Global Surveyor and Mars Odyssey data. Any explanation for the origin of the fan-shaped deposits must take into account both the similarities and differences in their morphologies, their approximately similar Amazonian age, and the fact that all three occur on the west-northwestern sides of the volcanoes [1]. Based on Viking Orbiter data, several models have been proposed for their formation, including massive landslides [2], glacial processes [3,4,5,6] and pyroclastic flows [6]. Williams [3] and Lucchitta [4] suggest that the fan-shaped deposits are the result of the deposition of moraines due to recession of local ice caps that formed on the volcanoes from mixtures of emanated volatiles and erupted ash [4]. Scott et al [6] suggest an explanation combining glacial and volcanic processes.

The Pavonis fan-shaped deposits (Figure 1) extend approximately 250 km northwest of the shield base along a N35°W trend [5]. These deposits range from 3.0-8.5 km above the Mars datum and cover an area of about 7.5 x 10^4 km^2, approximately half of the area covered by the Arsia deposit.

***Ridged Facies*:** The ridged facies is present around the distal margins of the Pavonis deposits. A larger 50-100 m outer ridge defines the margins of the deposits with smaller 5-30 m inner ridges concentric to the outer margins. In addition to the distal margins, the ridged facies is observed in the central regions of the fan-shaped deposits, from the outer margins to the base of the shield. This aspect of the ridged facies is unique to Pavonis, although the Arsia ridged facies do appear to continue beneath the knobby facies [7].

We interpret these ridges as drop moraines formed at the margins of a retreating cold-based glacier [7]. The fact that these ridges can be seen in the most proximal regions of the fan-shaped deposits suggests that at least one major phase of retreat and deposition occurred. The ridges are superposed on underlying topography, including a lobate lava flow to the west, and are not deflected by obstacles. The fact that the ridged facies is observed up to elevations of 8.5 km above Mars datum on the northern flanks of Pavonis suggests that a large ice sheet may have covered a significant portion of the flanks of the shield.

***Smooth Facies*:** The smooth terrain covers an area of approximately 1.2 x 10^4 km^2 and is mainly concentrated in one continuous deposit north of the shield extending into the central regions of the fan-shaped deposits. The smooth deposits are characterized by broad, gentle slopes and vast dune fields covering the surface. Based on new data, we interpret the smooth terrain to be debris-covered residual ice from the last major ice sheet present at Pavonis [8].

Knobby Facies: The knobby or hummocky facies is concentrated in the northeastern and western regions of the Pavonis fan-shaped deposits, and is absent from the central regions. It appears to superpose underlying features including the ridged facies and flow-like features. We interpret the knobby facies as a sublimation till derived from *in situ* downwasting of ash-rich glacier ice [7].

Flow-like Features: An area of several unique flow-like features exists in the western regions of the fan-shaped deposits (Figure 1) which have been termed "lobate flow features" [5]. These features are morphologically different from subaerial lava flows at higher elevations on the flanks of Pavonis and also from the Tharsis Plains flows beyond the fan-shaped deposits to the west. They consist of elevated plateaus with leveed edges and steep walls, some with relief of over 500 m. High-resolution MOC images across these flow-like features reveal that they are superposed in places by the knobby facies, which continues uninterrupted onto the surrounding terrain. Based on Viking Orbiter data, Scott et al [6] identify these features as elongate, sinuous ridges and suggest that they may be eskers formed by deposition of sedimentary material beneath or within a wasting ice sheet. They suggest an alternative explanation that these features may be unique lava flows originating from troughs on the lower western flank of Pavonis [5, 6]. MOLA topography data have revealed that these features are most likely lava flows, however, their steep scarps and leveed edges are not characteristic of subaerial lava flows. A possible explanation for these features involves subglacial eruptions [9]. This would be consistent with the observation that the knobby (hummocky) facies appears to superpose some of the flows without interruption. Subglacial flows of this volume would be expected to produce a significant amount of heat and meltwater. We have not observed any features indicative of large releases of subglacial water reservoirs similar to terrestrial jokulhlaups, however such features may not be associated with cold-based glaciers.

Radial Ridges: Several linear ridges are present in the central regions of the fan-shaped deposits. These ridges are radial to the base of the shield and have dimensions of approximately 100-200 m high**,** 1 km wide, and 30-60 km long**.** One of these ridges continues beneath the smooth terrain and another is superposed by the western flow-like features. They have previously been interpreted as levees at margins of a broad flow channel [10] and eskers [6]. Analysis of high-resolution MOC images suggests that these features may be radial dikes, which erupted in a subglacial environment [9].

Cold-Based Glacial Model: Temperatures on Mars are such that glacial activity is more likely to be similar to terrestrial polar glaciers (cold-based) as opposed to wet-based glaciers typical of more temperate latitudes [7]. The fan-shaped deposits of Pavonis Mons provide significant evidence in support of such a cold-based glacial model. The ridged facies bears a striking similarity to terrestrial drop moraines associated with recession and deposition by terrestrial cold-based glaciers such as the Antarctic Dry Valleys [7]. The relationship of the ridged facies to knobby facies may indicate two separate episodes of deposition.

Additional evidence in support of the glacial hypothesis is seen where Pavonis fan-shaped deposits are bounded to the east by lava flows from Pavonis and Ascraeus Mons (Figure 1). A large scarp exists in these regions where the fan-shaped deposits are 200-250 m lower than the surrounding lava plains. It appears that these lava flows were deflected from flowing toward lower topographic areas and continue for over 100 km to the north. This type of behavior would not be physically possibly unless some obstacle was present to deflect the flows. The most likely candidate would be a large ice sheet with a relief of at least 250 m that existed at the time of lava emplacement.

Origin of Proposed Glacier: The obliquity of Mars varies chaotically between 0° and 60° [11]. The proposed ice sheet could have formed during periods of high obliquity where equatorial regions receive less solar insulation than the poles and can become cold traps [12]. Under these conditions, significant evaporative loss of any volatiles at the poles would occur [12]. These evaporative losses would increase the atmospheric volatile content, eventually resulting in precipitation at cold traps. Thus, “at high obliquities (>35°), significant amounts of water could be transported equatorward to be deposited as ice at low latitudes” [13]. It is possible that during periods of high obliquity, “a localized icecap could have been enhanced by orographic effects on wind circulation" [13]. This process involves the same principle as a terrestrial rain shadow where an air mass with high moisture content is forced upward by the topography of the surface below. As the air mass moves upward, the moisture is precipitated out on the windward side of the obstacle, leaving the lee side in a “rain shadow”. The fact that all three of the Tharsis Montes fan-shaped deposits are observed on the west-northwestern side of each shield would indicate that regional winds out of the west-northwest existed at the time of deposition.

If these ice caps forming during times of active volcanism, their composition could be influenced by erupted volatiles and ash [4]. The proposed ice sheets undoubtedly contained a significant amount of englacial and supraglacial dust or ash. This debris would be deposited as the ice sublimated and retreated, forming the features of the fan-shaped deposits.

References: [1] K Edgett, LPSC 20, 256, 1989; [2] Carr et al, JGR, 82, 3985, 1977; [3] R Williams, GSA 10, 517, 1978; [4] B Lucchitta, Icarus, 45, 264, 1981; [5] J Zimbelman and K Edgett, LPSC 22, 31, 1992; [6] Scott et al, USGS Geol. Map, 1998; [7] J Head and D Marchant, Sub. to Geology, 2002; [8] D Shean and J Head, This Issue, 2002; [9] L Wilson and J Head, Geol. Soc. SP202, 2002; [10] C Hodges and H Moore, USGS Prof. Paper 1534, 1994; [11] J Laskar and P Robutel, Nature, 362, 608, 1993; [12] B Jakosky and M Carr, Nature, 315, 559, 1985; [13] M Carr, Water on Mars, 1996.

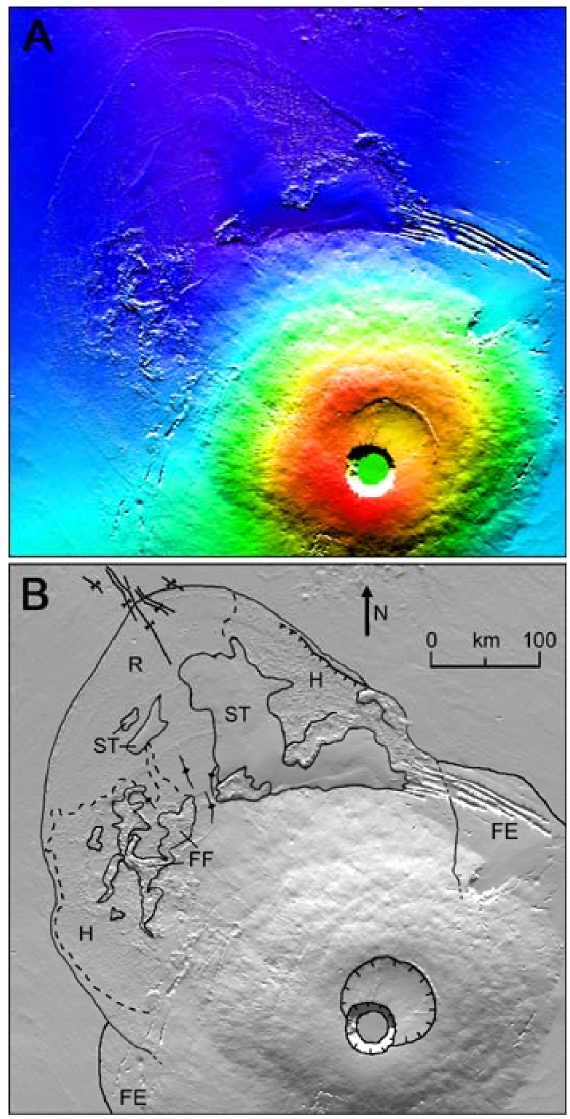

Figure 1: a) MOLA topography of Pavonis Mons and associated fan-shaped deposits; b) Sketch map of area with ridged facies (R), smooth facies (ST), hummocky/knobby facies (H), flow-like features (FF), flank eruptions (FE) are not associated with fan-shaped deposits.